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Development and Implementation of Escapement Goals for the Early Return of Sockeye Salmon to the Russian River, Alaska

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DEVELOPMENT AND IMPLEMENTATION OF ESCAPEMENT GOALS FOR THE EARLY RETURN OF SOCKEYE SALMON TO THE RUSSIAN RIVER, ALASKA[1]

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Alaska Department of Fish and Game
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ABSTRACT

The Russian River, a clearwater tributary to the Kenai River, supports the largest recreational fishery for sockeye salmon *Oncorhynchus nerka* in Alaska. The sockeye salmon stocks of the Kenai River return in two temporal components; an early-run return and a late-run return. The early run, which is the focus of this report, has been managed since 1979 based on an escapement goal of 9,000 spawners as established by the Alaska Board of Fisheries. This goal was evaluated based on returns since 1979. A new goal and the methods used to derive it are presented. In addition, possible management actions that can be implemented to assure that the goal is met are presented.

KEY WORDS: Russian River, sockeye salmon, *Oncorhynchus nerka*, management objectives, escapement goal, return per spawner, production per spawner, migratory timing.

INTRODUCTION

The Russian River is a clearwater stream near Cooper Landing, Alaska. The drainage includes two large clearwater lakes, Upper and Lower Russian Lakes, and terminates in the glacially-turbid Kenai River approximately midway between Kenai and Skilak Lakes (Figure 1). The largest recreational fishery for sockeye salmon *Oncorhynchus nerka* in Alaska occurs in the Russian River and at its confluence with the Kenai River. Annual effort by anglers in this fishery has exceeded 450,000 angler-hours and annual harvests have exceeded 190,000 fish (Figure 2). Unknown numbers of sockeye salmon of Russian River origin are also harvested by the sport fishery in the mainstem of the Kenai River and in the personal-use and commercial fisheries of Upper Cook Inlet.

Sockeye salmon return to the Russian River in two temporal components, henceforward referred to as the early-run and late-run returns. Early run fish typically arrive at the confluence of the Russian River with the Kenai River in early June and remain in the confluence area for up to 2 weeks before continuing their migration upstream into the Russian River. By mid-July, these fish have typically migrated through the Russian River and into Upper Russian Lake. The early run spawns exclusively in tributaries to, and shoals of, Upper Russian Lake, with most spawning occurring in Upper Russian Creek (Nelson 1973, 1974). The early-run return is comprised primarily of age 1.3[1] fish which are believed to spend their freshwater residency in Upper and Lower Russian Lakes (Nelson 1973-1985). Late-run sockeye salmon arrive at the confluence in mid to late July, move almost immediately into the Russian River, and are present in the area open to fishing through August. Late-run fish are comprised of two segments: those that spawn upstream of Lower Russian Lake and those that spawn downstream of Lower Russian Lake. The first segment spawns in tributaries to Upper and Lower Russian Lakes, shoals along the two lakes, and in the river section between the two lakes. These fish are primarily age 2.2 and are believed to spend their freshwater residency in the two lakes. The other segment spawns in the Russian River downstream of Lower Russian Lake. These fish, which have been reported to be primarily age 1.3, are more closely associated with the age structure of sockeye salmon which spawn in the mainstem Kenai River (Cross et al. 1983, 1985, 1986). These fish are believed to spend their freshwater residency in Skilak Lake.

The Sport Fish Division of the Alaska Department of Fish and Game regulates the recreational fishery to ensure that a minimum number of spawning sockeye salmon for each run pass through a weir at the outlet of Lower Russian Lake. Current goals, as established by Alaska Board of Fisheries policy in 1979, are 9,000 spawners for the early-run and 30,000 spawners for the segment of the late run which returns to the Upper and Lower Russian Lakes (Appendix A1). The early-run goal was based on an evaluation of available spawning habitat in upper Russian Creek while the late-run goal was based on

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[1] European notation: the first numeral refers to the number of years of freshwater residency and the second numeral refers to the number of years of marine residency. Total age is the sum of the marine and freshwater residencies plus one.

CONFLUENCE OF KENAI and RUSSIAN RIVERS

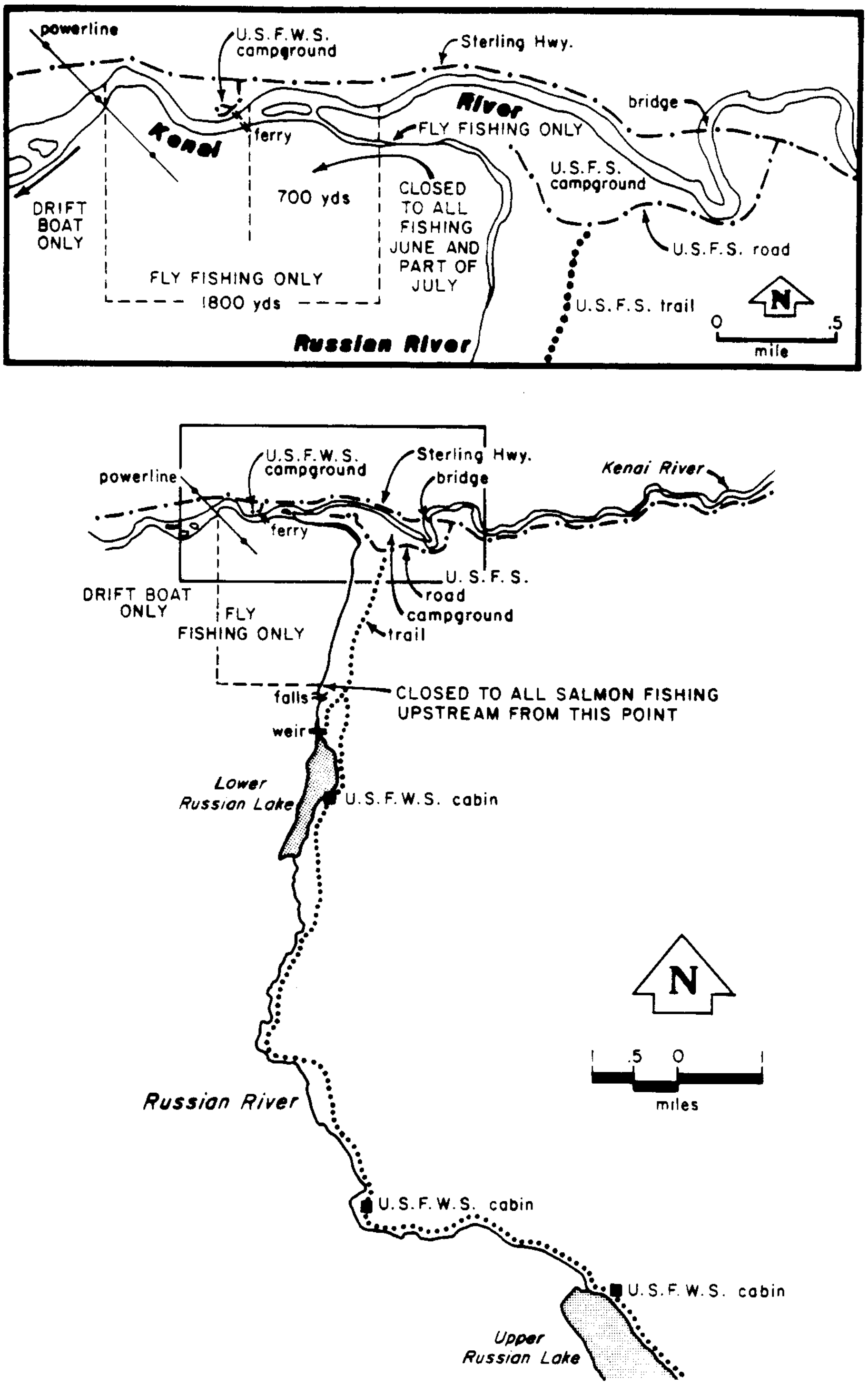
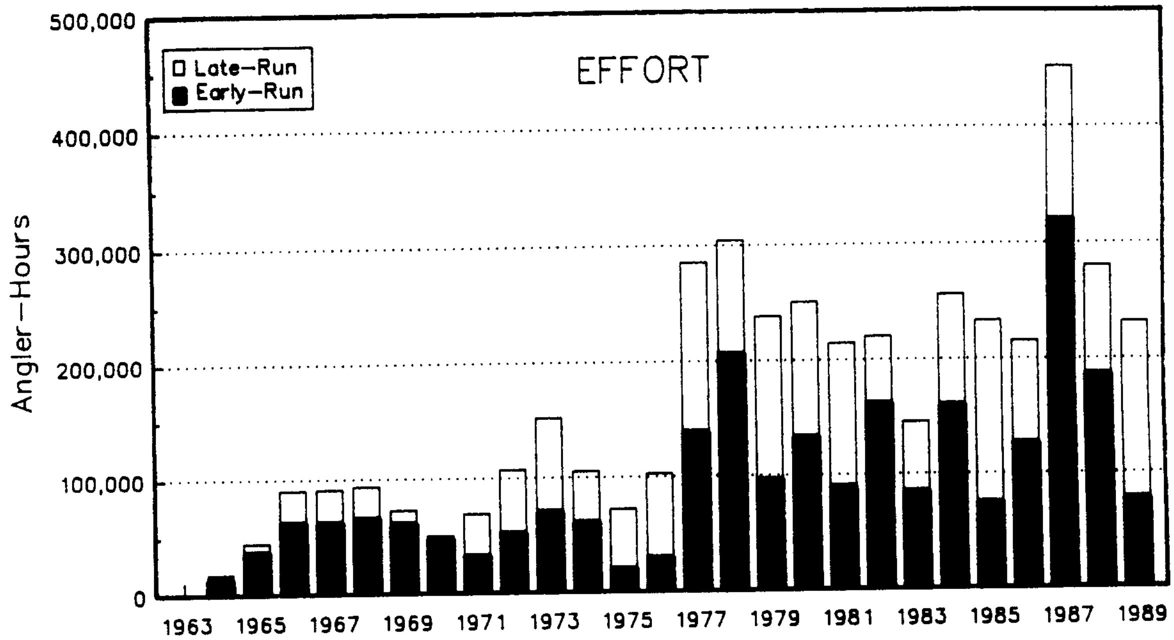


Figure 1. The drainage of the Russian River, Alaska.



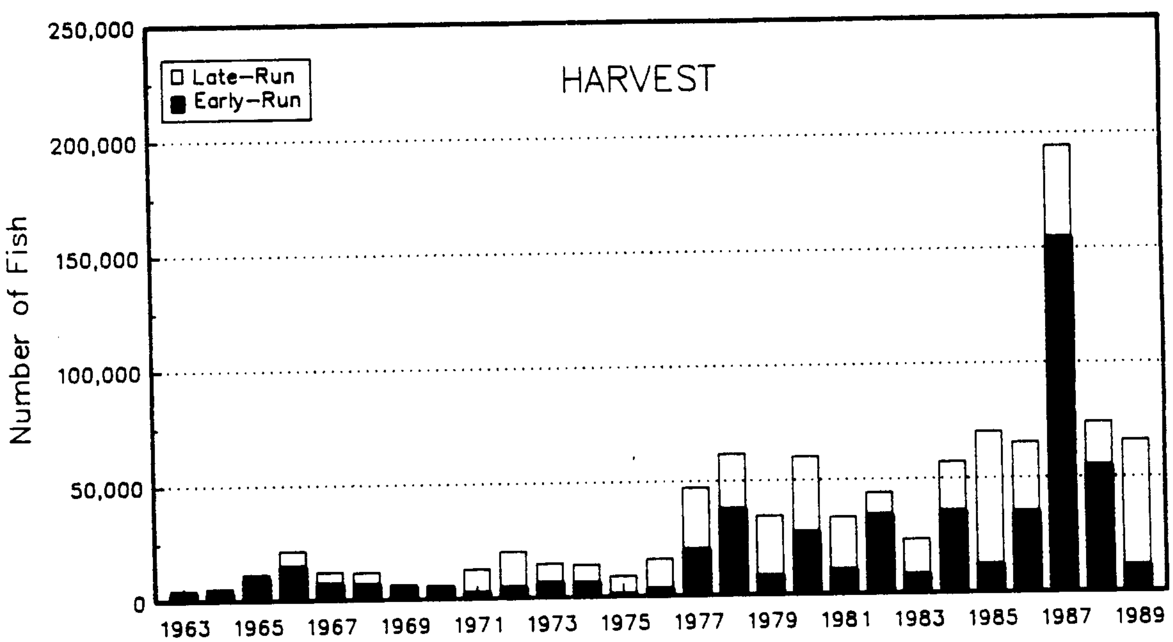


Figure 2. Effort and harvest in the sport fishery for early and late returning sockeye salmon to the Russian River, 1963-1989.

an evaluation of average rates of return-per-spawner (Nelson 1976). The early-run goal was informally raised to 16,000 spawners in 1989 based on evaluation of brood years returns from 1979 to the present (Carlon and Vincent-Lang 1990). The early-run goal of 16,000 spawners was not achieved in 1989.

From 1 June through 20 August, the daily bag and possession limit for sockeye salmon harvested from the Kenai/Russian River fly-fishing only area (Figure 1) is three fish over 406 mm (16 in) or more in length. Within this area, from a marker located 540 m (600 yd) downstream from the Russian River falls to a marker located on the Kenai River 1,620 m (1,800 yd) downstream of the confluence with the Russian River, only a single-hook unbaited, unweighted fly with a point-to-shank measurement of 9.5 mm (3/8 in) or less constituted legal terminal tackle. Any weights attached to the line are required to be a minimum of 457 mm (18 in) above the hook. To protect holding fish, a portion of the confluence area (termed the sanctuary) is closed to sport fishing until early-run spawning escapement can be projected to be met. Late-run fish do not typically hold in this area. Current bag and possession limits are three fish daily and in possession. The drainage is closed to fishing upstream of the lower 3 miles to allow fish to migrate unimpeded to spawning destinations.

The recreational fishery for sockeye salmon in the Russian River is the largest in the state in terms of angler effort and there is clearly the potential for overharvest. Management of this fishery requires precise and timely decisions to ensure that adequate escapement is obtained. The data necessary for these decisions are provided by a creel survey and a counting weir. The creel survey provides in-season data on angler effort and harvest while the weir counts provide daily escapement. Estimates of the total inriver return (harvest plus escapement) and the age, sex, and size compositions of the return provide information used to evaluate production and to estimate optimum spawning escapement levels.

The objective of this report is to present a recommended escapement goal for the early-run return of sockeye salmon to the Russian River based on data collected since the adoption of the goals in 1979. In addition, management actions that can be implemented to assure that the goal is met are presented. Because the stock-specific harvests of late-run returning sockeye salmon of Russian River origin in the various mixed-stock fisheries that harvest these fish have not been determined to date, production data are currently unavailable to assess the late-run return. We are currently investigating methods to assess these harvests and hope to present specific findings in a future report.

STOCK STATUS

The early-run return of sockeye salmon has not been subjected to harvest in the commercial fisheries of Upper Cook Inlet since the early 1970s. These fisheries do not open by regulation until 25 June, a time when nearly all the early-run fish have moved into the Kenai River. Also, few early-run fish have been harvested in the sport fisheries of the mainstem Kenai River and in the personal-use fisheries of Upper Cook Inlet. Given this, the predominant exploiter of the early-run stock has been the recreational sport fishery that operates in the Russian River and its confluence with the Kenai River. Effort and harvest in this sport fishery has been estimated since 1963 and is presented by Lawler (1963, 1964), Engel (1965-1972), Nelson (1973-1985), Nelson et al. (1986), McBride and Athons (1987), Hammarstrom and Athons (1988, 1989), and Carlon and Vincent-Lang (1990). The sport harvest of early-run sockeye salmon in this recreational fishery has averaged nearly 20,000 fish from 1963 to 1990, ranging from 154,200 in 1987 to only 1,400 fish in 1975 (Table 1, Figure 3). Angler-effort during this period has averaged nearly 98,000 angler-hours, ranging from 13,602 in 1964 to nearly 320,000 angler-hours in 1987 (Table 1, Figure 3).

The spawning escapement of the early-run return of sockeye salmon to the Russian River has been censused since 1963 from counts of salmon passed through a weir located 100 meters downstream of the outlet of Lower Russian Lake (Lawler 1963 and 1964, Engel 1965-1972, Nelson 1973-1985, Nelson et al. 1986, McBride and Athons 1987, Hammarstrom and Athons 1988 and 1989, Carlon and Vincent-Lang 1990). The early run spawns exclusively upstream of this weir. Most early-run fish spawn in Upper Russian Creek (Nelson 1973, 1974); however, others also spawn in other small tributaries to, and shoals of, Upper Russian Lake (observation made during 1990 by authors). The spawning escapement of early-run fish has averaged 21,600 fish during this period, ranging from 2,650 in 1971 to 61,520 in 1987 (Table 1, Figure 4A).

The sport fishery has exploited an average of 40% of the total early-run return to the river (Table 1, Figure 4B). Exploitation by the inriver sport fishery has ranged from 18.7% in 1976 to 71.5% in 1987. There is a strong positive correlation ($r = 0.95$, $P < 0.001$) between the number of early-run sockeye salmon harvested in the sport fishery and those which return to the river (Figure 5), indicating that the harvest in the early-run sport fishery is related to abundance.

The early run has been reported to be comprised primarily of age 1.3 fish (Nelson 1973). Data collected since 1973, however, indicate that the early-run return is comprised primarily of 2.X fish (Appendix B1). For the years surveyed, there have been no significant differences in the age compositions of the sport fishery and spawning escapement (McBride and Athons 1987, Hammarstrom and Athons 1988, Carlon and Vincent-Lang 1990).

FORMULATION OF ESCAPEMENT GOAL

Management of sockeye salmon stocks in Alaska is most often based on achieving a predetermined level of spawning escapement that maximizes the probability of providing for some level of sustained yield of the resource. For example, Bristol Bay sockeye salmon stocks are managed to assure for optimal spawning escapements into eight of the largest spawning systems (Minard and Meacham 1987). Optimal escapement goals for each system are based on spawner-recruit relationships. Management ranges are set around each optimal escapement goal at values that would produce 95% of the maximum sustained yield of the stock. Cook Inlet sockeye salmon stocks are also managed based

Table 1. Historical effort and harvest in the sport fishery, spawning escapement, total return, and estimated sport exploitation of the early-run sockeye salmon return to the Russian River, Alaska.

Year	Sport Effort (Ang-Hrs)	Sport Harvest	Spawning Escapement	Total Return	Percent Exploitation
1963	Unknown	3,670	14,380	18,050	20.3%
1964	13,602	3,550	12,700	16,250	21.8%
1965	37,707	10,030	21,710	31,740	31.6%
1966	63,080	14,950	16,660	31,610	47.3%
1967	62,957	7,240	13,710	20,950	34.6%
1968	66,538	6,920	9,200	16,120	42.9%
1969	61,789	5,870	5,000	10,870	54.0%
1970	48,729	5,750	5,450	11,200	51.3%
1971	33,059	2,810	2,650	5,460	51.5%
1972	52,500	5,040	9,270	14,310	35.2%
1973	70,947	6,740	13,120	19,860	33.9%
1974	61,333	6,440	13,150	19,590	32.9%
1975	20,588	1,400	5,640	7,040	19.9%
1976	28,914	3,380	14,700	18,080	18.7%
1977	138,583	20,400	16,070	36,470	55.9%
1978	196,585	37,720	35,850	73,570	51.3%
1979	96,300	8,400	19,700	28,100	29.9%
1980	130,815	27,220	28,670	55,890	48.7%
1981	103,134	10,720	21,140	31,860	33.6%
1982	163,137	34,500	56,110	90,610	38.1%
1983	78,547	8,360	21,210	29,570	28.3%
1984	144,677	35,880	28,910	64,790	55.4%
1985	75,000	12,300	30,610	42,910	28.7%
1986	126,720	35,100	36,200	71,300	49.2%
1987	319,823	154,200	61,520	215,720	71.5%
1988	186,389	54,780	50,410	105,190	52.1%
1989	78,702	11,285	15,338	26,623	42.4%
1990[a]	178,228	24,310	25,739	50,049	48.6%
Mean	97,718	19,963	21,601	41,564	40.3%

[a] Preliminary estimate

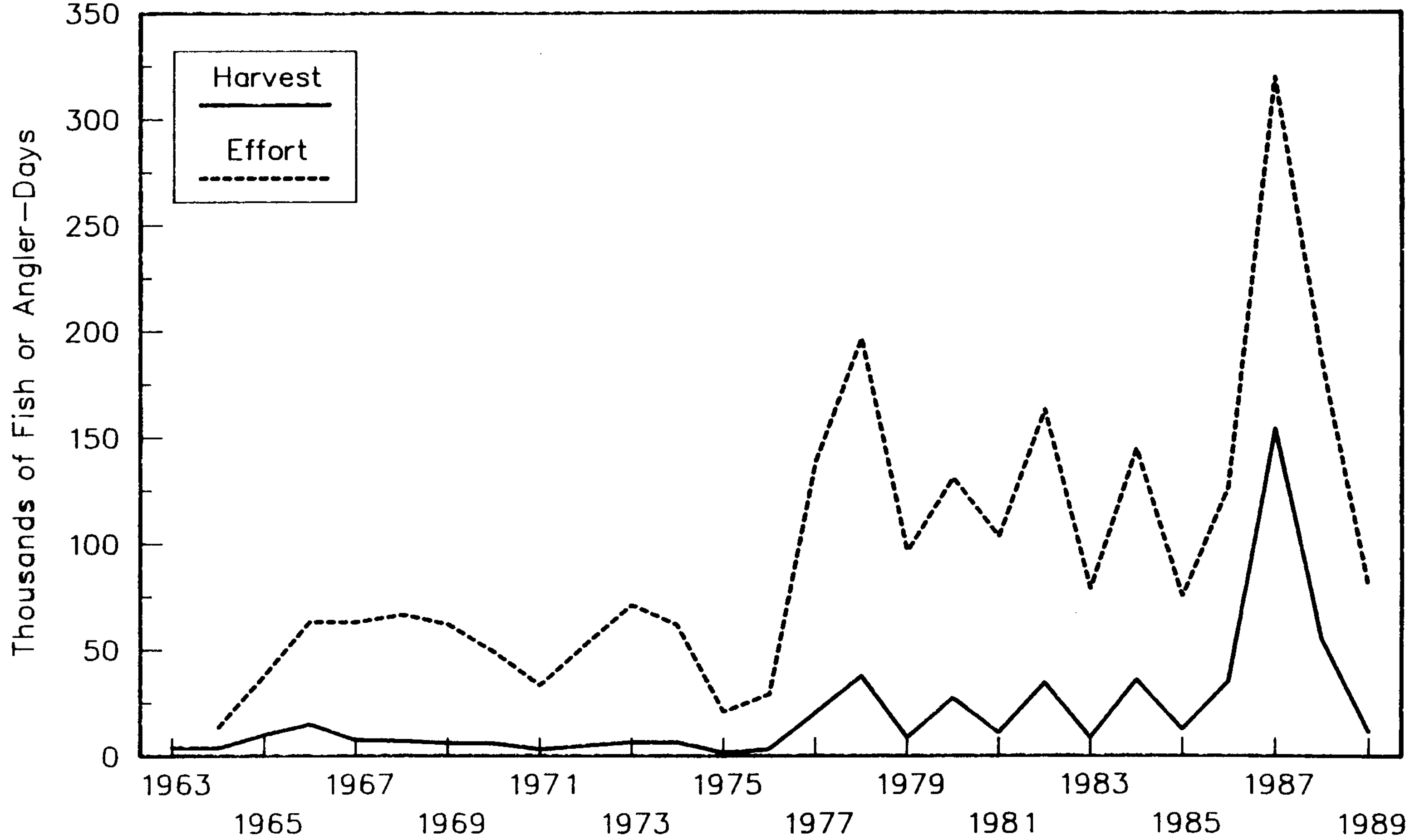


Figure 3. Effort and harvest of sockeye salmon during the sport fishery for early-run sockeye salmon returning to the Russian River, Alaska, 1963-1989.

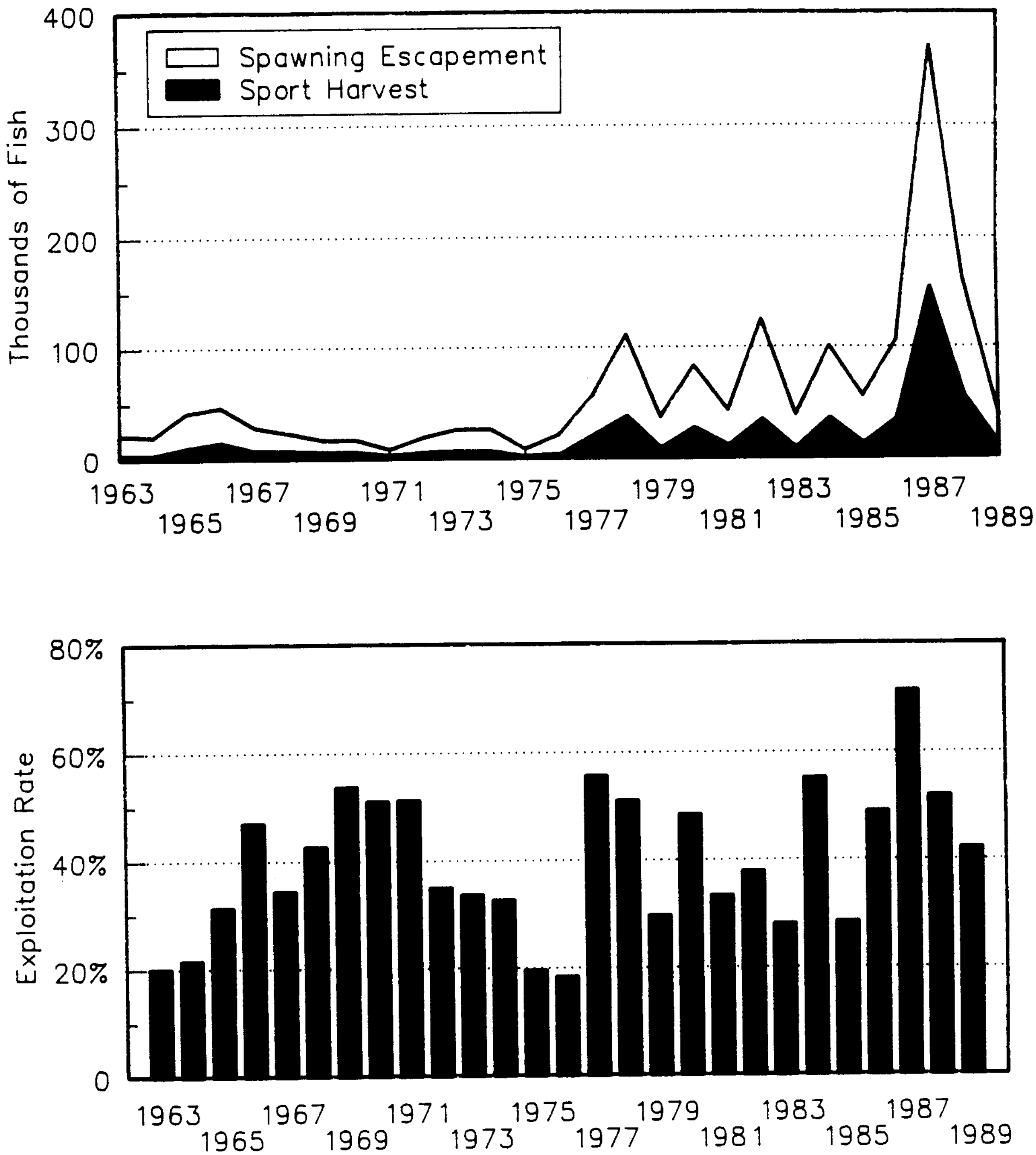


Figure 4. Spawning escapement and sport harvest of early-run sockeye salmon returning to the Russian River, Alaska, and percent exploitation by the sport fishery, 1963-1989.

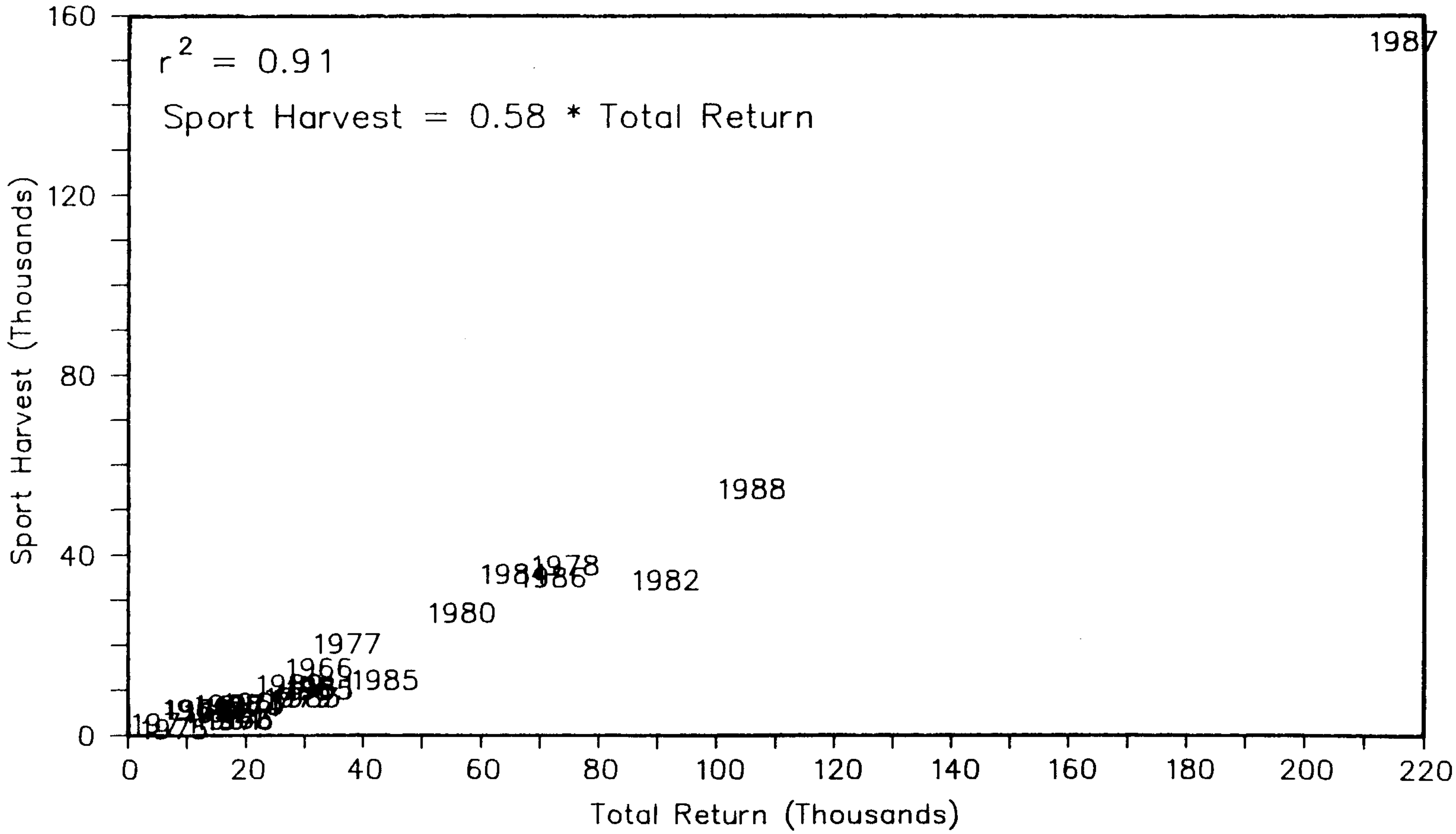


Figure 5. Relationship between the total return and the number of fish sport harvested during the early-run return of sockeye salmon to the Russian River, Alaska, 1969-1983.

on optimal spawning escapements to major spawning systems (Tarbox and Waltmeyer 1984). Optimal escapement goals in Cook Inlet are developed based on spawner-recruit relationships, or in the absence of these data, lake or spawning area productivity relationships.

The current escapement goal for the early-run return of sockeye salmon to the Russian River is 9,000 spawners (Appendix A1). This goal, as established by Alaska Board of Fisheries policy in 1979, was based on an evaluation of the maximum available spawning habitat in Upper Russian Creek (Nelson 1976). At the time of its development, it was assumed that early-run sockeye salmon spawn exclusively in this tributary. The goal was therefore assumed to maximize for the probability of providing for maximum sustained yield of the early-run stock. In all years since its establishment, the goal of 9,000 spawners has been meet. Recent survey data, however, indicate that other areas are used for spawning by early-run fish returning to the Russian River system (observation by authors). Also, additional years of production data are available since establishment of the current goal. For these reasons, we choose to re-evaluate this goal based on data collected since the adoption of the goal in 1979.

Selection of an appropriate data base for establishing escapement goals for the returns of a salmon stock depends largely to the degree to which the population dynamics of a particular stock and the fisheries exploiting that stock are understood. Since complete brood tables of returns are available for the early-run return of sockeye salmon to the Russian River (Appendix B1), calculation of spawner production, surplus production[2], and production-per-spawner statistics are possible for this stock (Table 2). For this reason, we choose to evaluate the escapement goal for the early-run stock based on spawner-recruit data. Determination of the availability and productivity of uninventoried spawning habitat area is determined to be not feasible at present.

There are several models that describe the theoretical relationship between the number of spawners and their subsequent production. The most common of these theories for salmon management applications is the Ricker model (Ricker 1954). This model assumes that there is an escapement at which production for a system is maximized and that escapements below and above this level result in reduced production. For this reason, application of the Ricker model requires that a range of spawning escapements are available that describe the full range of possible spawner productions for the system. For the early-run return, this does not appear to be the case. Although there appears to be a range of escapements which describe possible spawner productions below maximum sustainable levels, there are no adult return data available describing the effects of large escapements above this level. The largest production (274,000) on record occurred for the largest escapement (56,000) on record (Figure 6). This indicates that even higher levels of production may be possible with increased spawning escapements. Given this,

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[2] Surplus production is the level of subsequent production in excess of the spawners that produced that production.

Table 2. Spawner escapement, sport harvest, total return, and subsequent production and return-per-spawner for the early-run return of sockeye salmon to the Russian River, Alaska.

Brood Year	Spawner Escapement	Sport Harvest	Total Return	Spawner Production	Return per Spawner
1969	5,000	5,870	10,870	13,269	2.65
1970	5,450	5,750	11,200	12,777	2.34
1971	2,650	2,810	5,460	7,668	2.89
1972	9,270	5,040	14,310	100,006	10.79
1973	13,120	6,740	19,860	26,548	2.02
1974	13,150	6,440	19,590	52,624	4.00
1975	5,640	1,400	7,040	15,947	2.83
1976	14,700	3,380	18,080	113,309	7.71
1977	16,070	20,400	36,470	17,675	1.10
1978	35,850	37,720	73,570	16,936	0.47
1979	19,700	8,400	28,100	94,843	4.81
1980	28,670	27,220	55,890	42,987	1.50
1981	21,140	10,720	31,860	75,311	3.56
1982	56,110	34,500	90,610	273,986	4.88
1983	21,210	8,360	29,570	23,549	1.11
1984	28,910	35,880	64,790	38,801	1.34
Mean	18,540	13,789	32,329	57,890	3.38

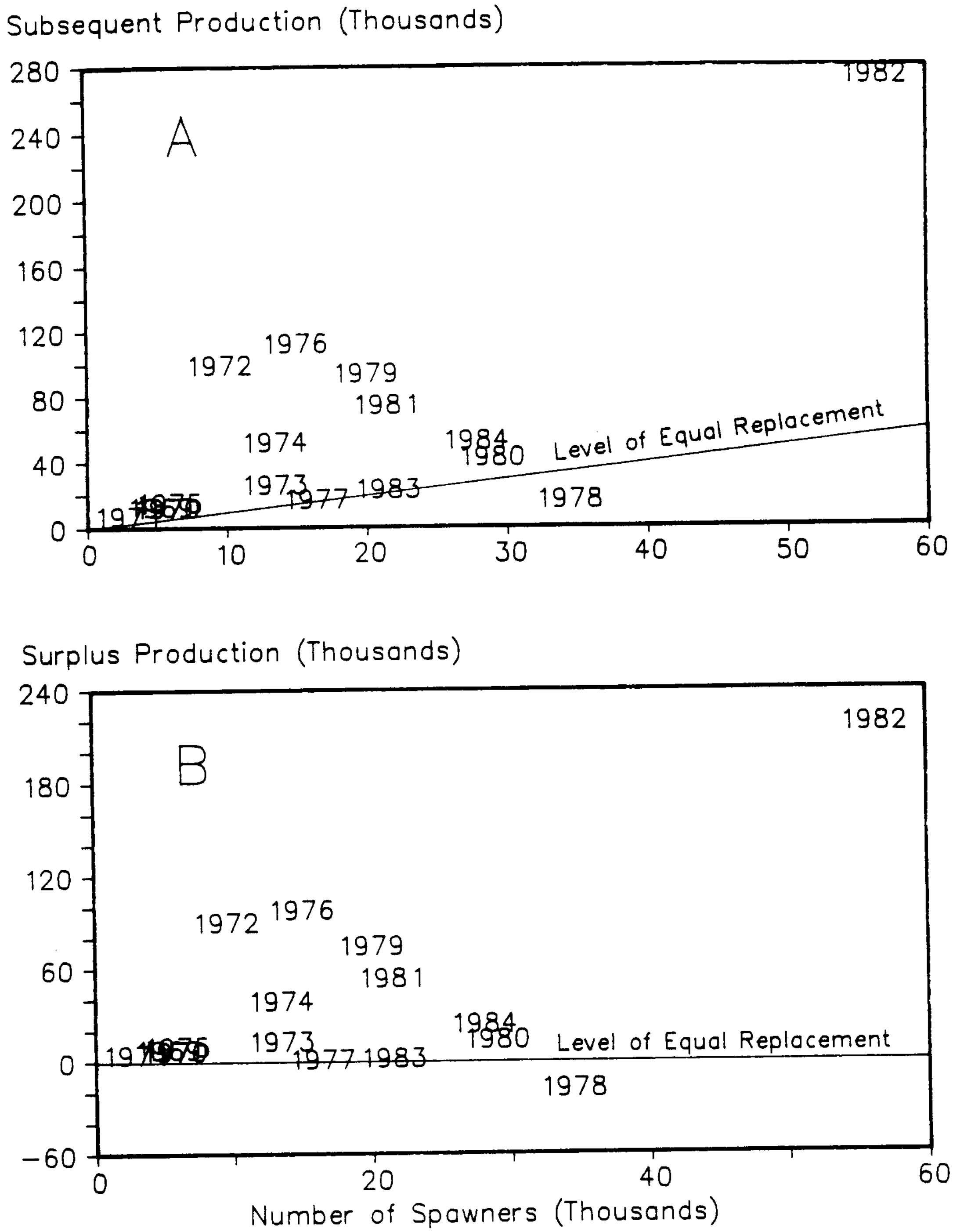

Figure 6. Relationship between the number of early-run spawners and their subsequent and surplus production for the early-run return of sockeye salmon to the Russian River, Alaska, 1969-1984.

we chose not to apply the Ricker model to this data set. However, it can be concluded that maximum production for this stock occurs near 56,000 spawners.

Maximal production from spawning escapements typically occur when observed rates of production decline from their maximum (Ricker 1954). The highest rate of production (10.8) occurred for an escapement of 9,200 spawners (Table 2, Figure 7). This escapement, however, did not provide as high a surplus production (90,000 fish) as did the escapement of 56,000 spawners which resulted in a surplus production of 218,000 fish. This indicates that larger production may be sustainable with increased spawning escapements.

Factors other than the numbers of spawners can influence the production of sockeye salmon. One such potential factor for the early-run return of sockeye salmon to the Russian River is the interaction with the late-run return. To assess such possible interaction, we evaluated the relationship between (1) the numbers of late-run spawners returning in the same brood, and (2) the numbers of early and late-run spawners returning the previous year as explanatory variables influencing the production rate of the early-run return. If the Russian River system is spawning area limited, the numbers of late-run spawners in the same brood year should significantly influence the production rate of early-run spawners. This, however, does not appear to be the case. The number of late-run spawners that return in the same brood year does not appear to significantly ($r = 0.16$, $P = 0.566$) influence the early-run production rate (Figure 8A). This suggests that spawning habitat has not been a limiting factor. If the system were rearing habitat limited, the numbers of fry held over from the previous year should significantly influence the production rate of early-run spawners. This also does not appear to be the case. The numbers of early and late-run spawners that return in the previous brood year do not appear to significantly ($r = -0.06$, $P = 0.838$) influence the early-run production rate (Figure 8B). This suggests that the system is not rearing-habitat limited.

Environmental factors can also influence the production of sockeye salmon. Given that the system does not appear to be spawning or rearing habitat limited over the range of observed escapements, we explored three environmental factors which might influence egg-to-fry survival of a given brood year (i): total fall (August through November) precipitation during year i (to evaluate if fall floods impact egg-to-fry survival), mean January air temperature during brood year $i+1$ (to evaluate if cold winter temperatures impact egg-to-fry survival), and mean January precipitation during brood year $i+1$ (to evaluate if lack of winter snow cover impacts egg-to-fry survival). Of these factors, total fall precipitation during year i explained the largest amount of variability ($r = 0.51$, $P = 0.052$) in the production rate of early-run spawners (Figure 9A). Neither mean January air temperature ($r = -0.27$, $P = 0.340$) or precipitation ($r = -0.18$, $P = 0.512$) explained much of the observed variability in early-run production (Figure 9B and C).

Sockeye salmon fisheries in Bristol Bay have been shown to exhibit cyclic patterns in production (Eggers and Rogers 1987). To test whether the early-run return of sockeye salmon in the Russian River exhibited cycles in production, both production and production-per-spawner were plotted by year for the years of record (Figure 10). Although there appeared to be a 4-year cycle

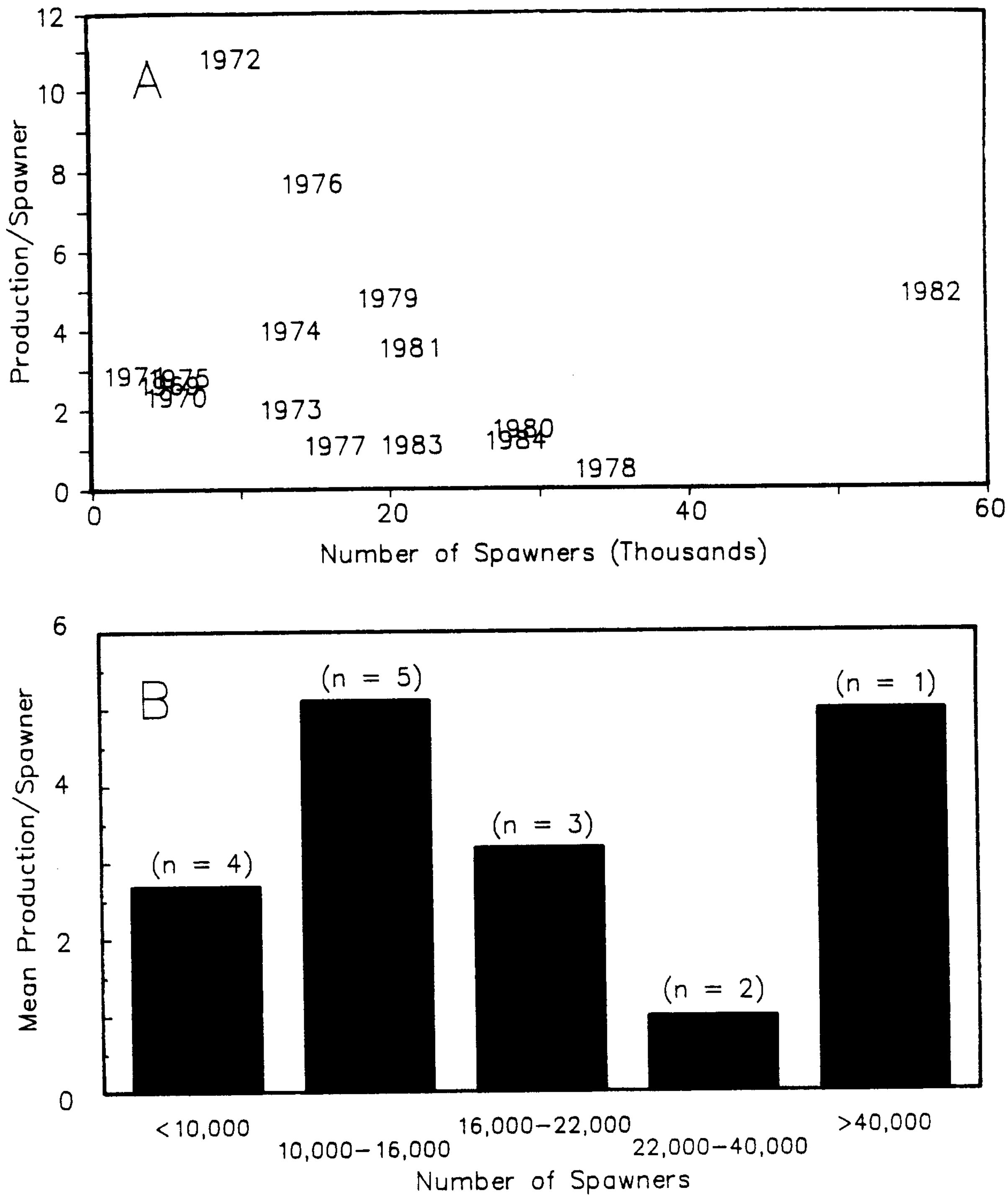

Figure 7. Relationship between the number of early-run spawners and their subsequent production-per-spawner for the early-run return of sockeye salmon to the Russian River, Alaska, 1969-1984.

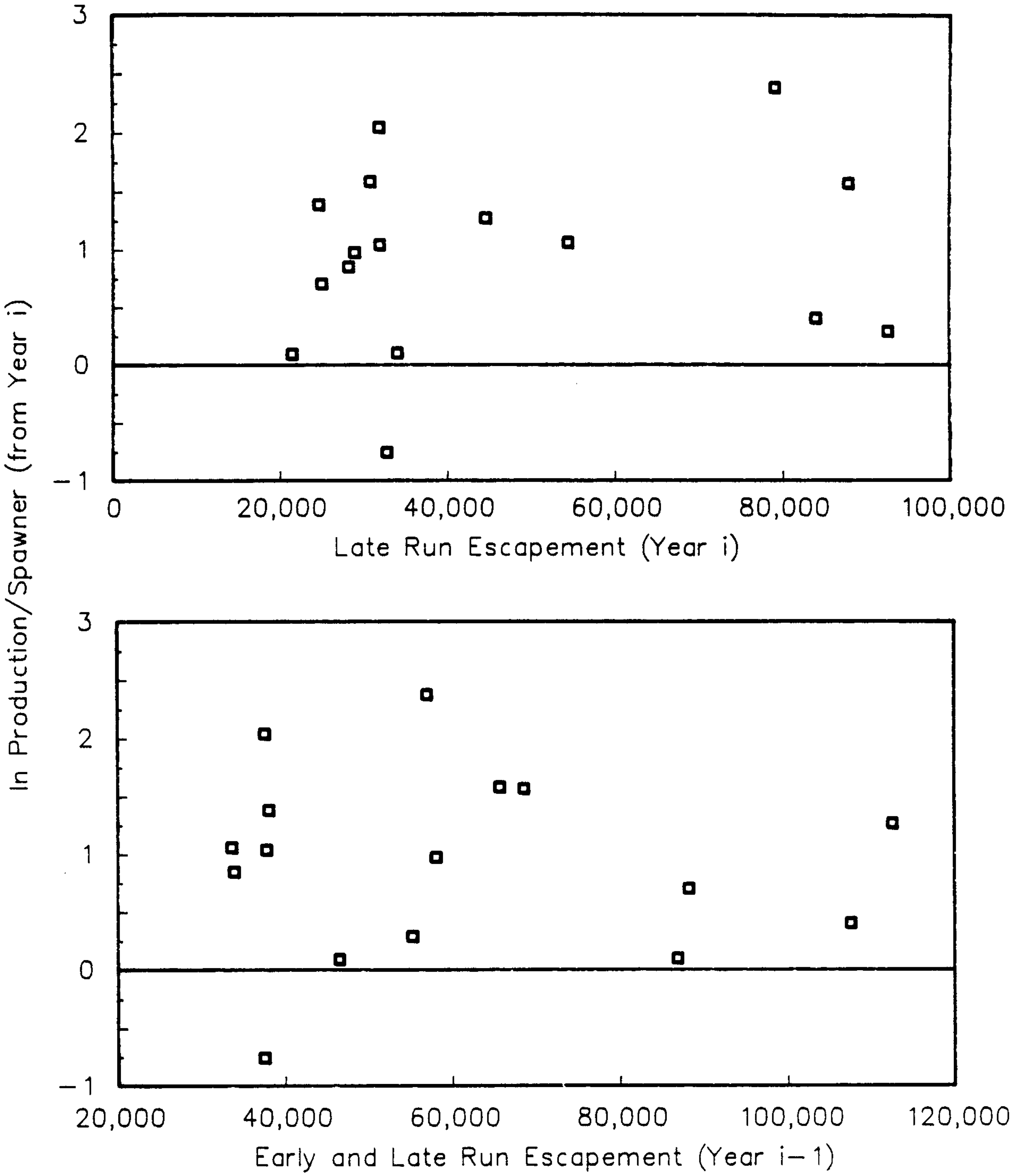

Figure 8. Influence of selected spawning and rearing habitat limiting variables on the production rate of early-run sockeye salmon returning to the Russian River, Alaska.

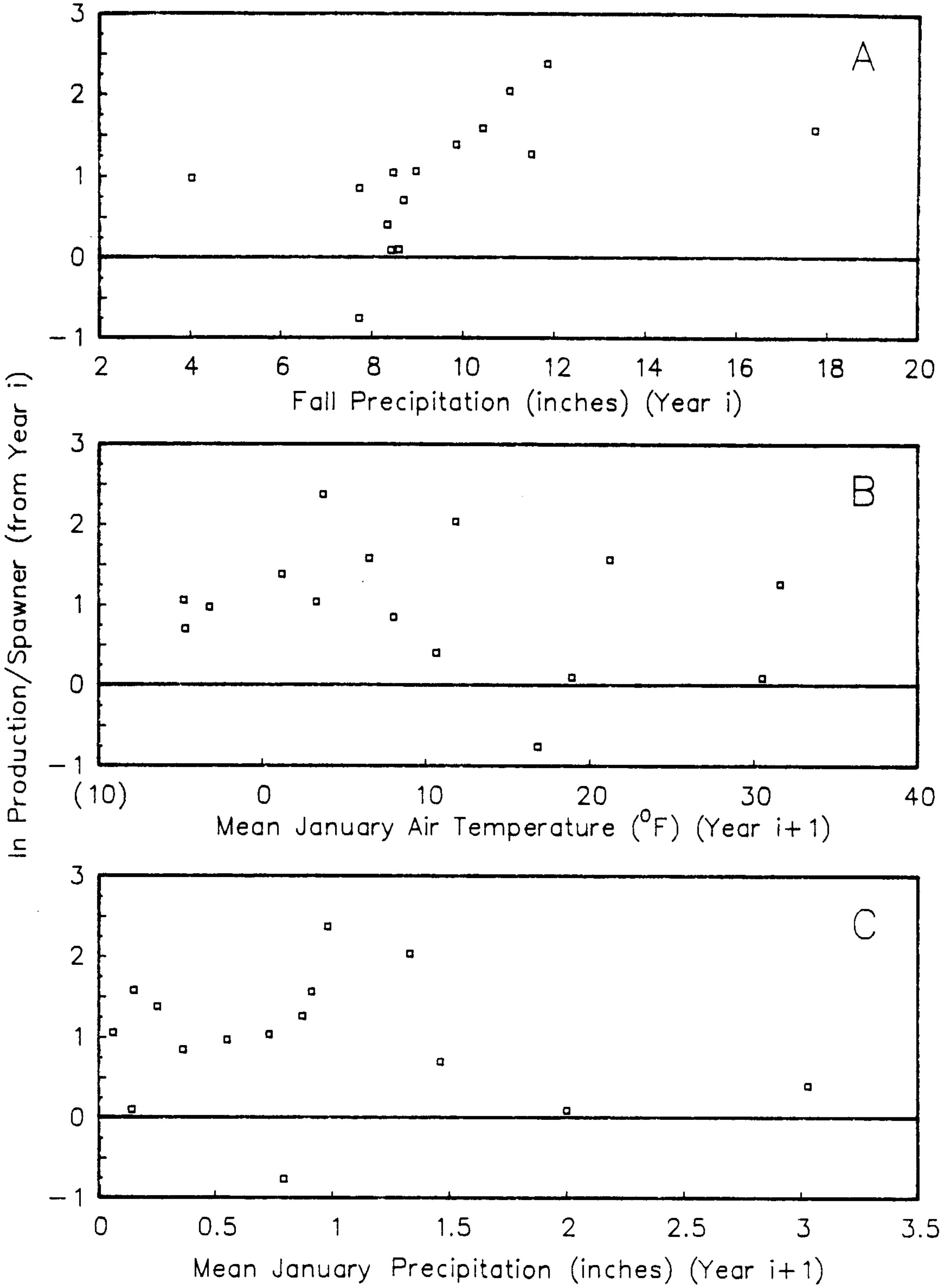

Figure 9. Relationship that selected environmental factors have on the production rate of early-run sockeye salmon returning to the Russian River, Alaska.

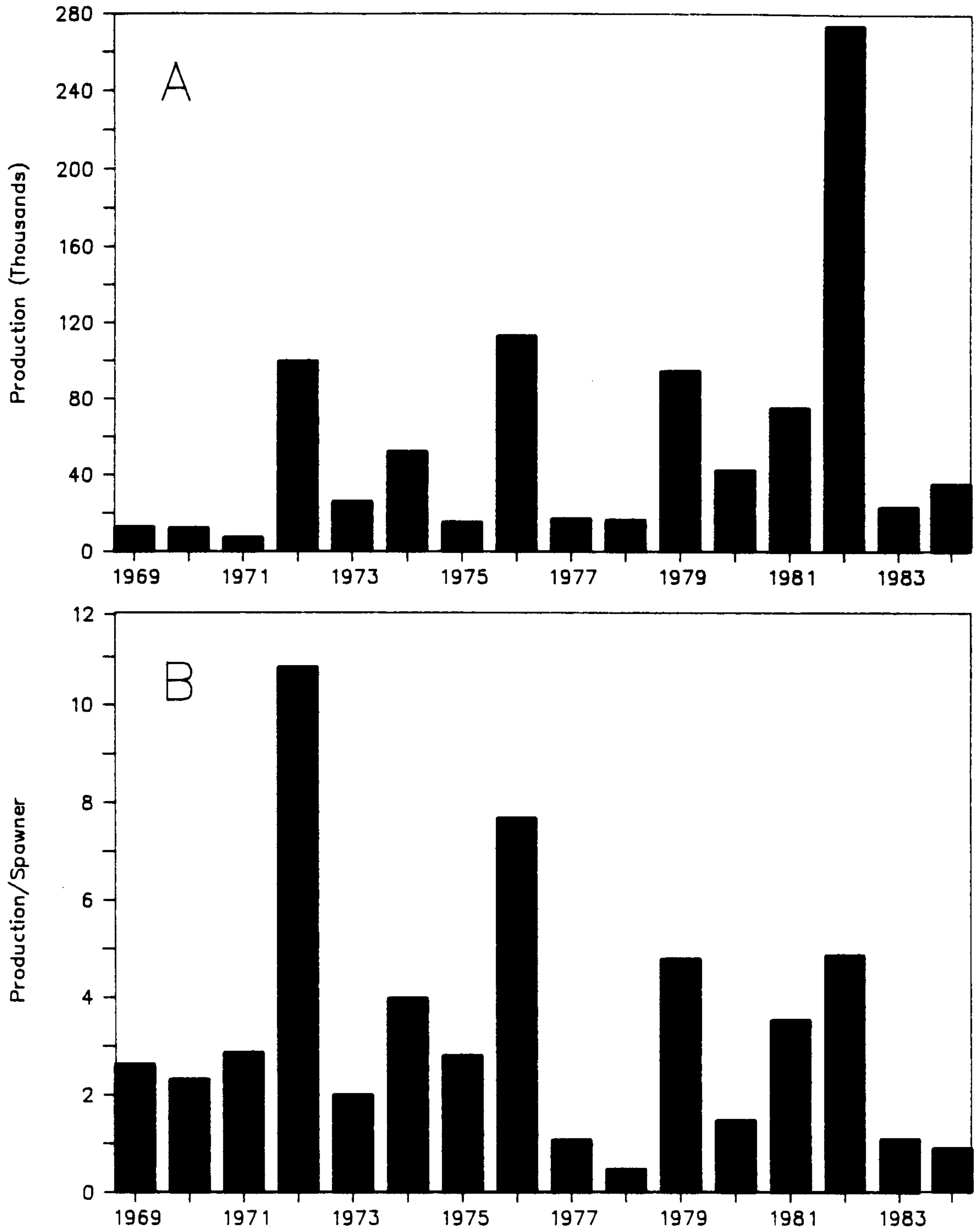

Figure 10. Annual spawner production and production-per-spawner for the early-run return of sockeye salmon to the Russian River, Alaska, 1969-1984.

for the years 1969-1976, this cycle broke down after 1977, suggesting that the early-run production is not cyclic.

It is our recommendation that the escapement goal for the early-run return of sockeye salmon to the Russian River be raised from its present level of 9,000 spawners. All available data indicate that this level of escapement is below the maximum sustainable level for this stock. Maximum production of this stock occurs near 56,000 spawners. Rates of production for the early-run stock are maximized in the range of 9,000 to 16,000 spawners. However, return data from the observed escapement of 56,000 suggest that higher productions may occur for spawning escapements near 56,000.

If the management goal is to maximize for the probability of achieving maximum sustained yield (MSY) of the early-run stock, the escapement goal should be raised from its current level of 9,000 to a point closer to the escapement which resulted in the highest measured production (56,000 spawners). However, in only 5 of the past 27 years have total returns of the early-run stock exceeded 56,000. Raising the goal to a level that would maximize for the probability of achieving MSY (56,000) at this time would therefore cause great hardship to the sport fishery exploiting this stock in that in nearly all years the fishery would need to be closed or severely restricted.

Managing a salmon stock to maximize the probability of achieving MSY has both positive and negative features. Although, on average, the highest productions will be achieved for a stock at MSY, productions near this level will display their greatest variability due to environmental factors. For a stock that is managed primarily for sport fishing interests, this may not be desired. Unlike a commercial fishery which can be relatively easily regulated through emergency openings to harvest all surplus production above a set escapement goal, sport fisheries do not usually possess such abilities due to inherent inefficiencies in fishing gear. Although bag and possession limits can be relaxed and closed areas opened during years of high return, such actions will often not be sufficient to harvest all surplus production such that the escapement goal is not exceeded. Also, some sport fisheries already have full angler participation and are fully utilized in terms of available time and area. Increasing bag and possessions limits in those situations may actually reduce individual opportunity to fish because it may lengthen the average angler-day in an already crowded fishery. Also, management of a sport fishery like the Russian River for MSY would require a complex regulatory package to deal with the high fluctuations in annual productions that would occur. Such variability in production and regulations are generally not desirable for a fully developed sport fishery or the commerce that depends on it. Management at a level below MSY may reduce average production but that loss is offset by the stability of the resulting fishery.

It is our opinion that the inriver sport fishery targeting the early-run sockeye salmon return has room for some expansion. Also, if the early-run return can be increased over time, a sport fishery targeting this stock in the mainstem Kenai River may be developed. Given this, it is our recommendation that the escapement for the early-run stock be raised. It is our recommendation that escapement be raised in a step-wise manner. This will allow for a gradual evaluation of the effects of increased production, allowing time to respond to changes in production through the standard regulatory process. As an initial step in this process, we recommend the goal be raised to 16,000. This level of escapement should be achievable in most years. Early-run escapements have exceeded 16,000 spawners in all years but one (1989, 15,338 spawners) since 1977. An escapement of 16,000 spawners should, based on an average rate of return of 5 fish per spawner (refer to Table 2 and Figure 3), produce on average a total return of about 82,000 early-run fish. Application of the historical exploitation rate (58%) for the sport fishery to a total return of 82,000 fish provides for an average harvest of 48,000 fish and an average escapement of 34,000 fish; well above the 16,000 fish escapement goal. This would allow the run to continue to build over time. For this reason, we recommend that the fishery continue to be managed such that:

1. the sanctuary area remain closed during the early run until escapement can be projected to exceed the established goal of 16,000 spawners (this is no change from the status quo),
2. bag or possession limits not be liberalized when escapement is projected above 16,000 spawners[3], and
3. the goal be re-evaluated after the returns of recent large spawning escapements can be determined.

IMPLEMENTATION OF THE ESCAPEMENT GOAL

An approach similar to that described by McBride et al. (1989) for managing returns of chinook salmon *O. tshawytscha* to the Kenai River, Alaska, can be used to manage the early-run return of sockeye salmon to the Russian River. Successful implementation of an established escapement goal using this approach requires timely and accurate projections of ultimate spawning escapement. For the Russian River, the following data bases can be used for estimating projected spawning escapement during the early-run: (1) historical timing of daily weir counts, and (2) historical timing of daily harvests in the river and confluence segments of the sport fishery. For the early run, daily escapements of early-run sockeye salmon spawners through the weir at the outlet of Lower Russian Lake are available from 1978[4] through 1989. Daily harvests in the river and confluence segments of the sport fishery can only be estimated for the years 1986, 1987, and 1988.

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[3] During their 1989 meeting, the Board of Fisheries gave the Department the authority to raise bag and possession limits when escapement could be projected to exceed an established goal by 25%.

[4] Although daily escapements are available for years prior to 1978, they have not been keypunched to date and were not used in this analysis.

Methods

Timing data bases can be evaluated using the migratory timing statistic (Mundy 1982). The migratory timing statistic can be used to describe the distribution over time of a salmon migration past any fixed location (a weir, sport fishery, etc.). Empirical distributions or daily cumulative proportions can be calculated for each year of data for each data base. In this case, the values in the data bases are daily counts or harvests. These values are accumulated for each run to calculate a total (N_i) for the run for each year (i). For each day, t, the accumulated value to date (n_t) can also be calculated. A cumulative proportion (p_{ti}) can then be calculated for each day (t) and year (i) as:

$$p_{ti} = n_{ti}/N_i \tag{1}$$

For each year i, the set P of all cumulative proportions ($p_{1i}, p_{2i}, \ldots, p_{ti}$) represents the annual empirical cumulative distribution function (CDF), where each p_{ti} is the cumulative proportion of the total that has passed by time or day (t). The midpoint of the migration, or median of the distribution, is reached or passed when p_{ti} is greater than or equal to 0.5.

For any day, the mean cumulative proportion, $p_{t.}$, over all years can be calculated as:

$$p_{t.} = \frac{1}{m} \sum_{i=1}^{m} p_{ti} \tag{2}$$

and its variance as:

$$\mathrm{Var}(p_{t.}) = \frac{1}{m-1} \sum_{i=1}^{m} (p_{ti} - p_t)^2 \tag{3}$$

For each data set, a mean migratory timing statistic was computed. Variance and 90% confidence intervals were also estimated for each cumulative proportion, $p_{t.}$. The median and the date at which the relative precision for the 90% confidence interval of the estimates of cumulative proportions was ≤20% of the point estimates were computed and compared for each data set.

Application

The data base describing daily escapements of early-run sockeye salmon spawners exhibited a relatively high degree of consistency between years. Mid-points of the seasonal escapements of early-run spawners ranged over 10 days from 25 June to 6 July (Appendix B2). The historical mid-point of the run occurs on 1 July (Table 3). The data base describing daily harvests of early-run sockeye salmon in the confluence and river segments of the sport fishery exhibited less consistency between years. Historical mid-points of the harvests occur on 24 and 27 June, respectively, for the confluence and river segments of the sport fishery (Table 3); however, there is a high

Table 3. Summary statistics for migratory timing of the early-run return of sockeye salmon to the Russian River, Alaska.

Data Base	Median Date	Point of distribution when RP[a] ≤ 20%: Date	Point of distribution when RP[a] ≤ 20%: Percent of Distribution
Sport Fishery			
Confluence Sport Fishery	24 June	03 July	86%
River Sport Fishery	27 June	08 July	91%
Weir			
All Returns	01 July	01 July	51%
Warm-Early Returns	28 June	30 June	63%
Cool-Late Returns	03 July	04 July	61%

[a] Relative Precision ($\alpha = 0.10$)

degree of annual variability in the timing of the mid-points (Appendices B3 and B4).

The timing data that describes cumulative spawning escapement can be used in-season to estimate the expected total spawning escapement. Since n_{ti} represents the number passed by day (t) in year (i), then the expected total for that year can be calculated as:

$$\hat{T}_i = \frac{n_{ti}}{p_{t.}} \tag{4}$$

The variance of $\hat{T}_i$ can be estimated as:

$$Var(\hat{T}_i) = n_{ti}^2/p_{t.}^2 \; (Var[n_{ti}]/n_{ti}^2 + Var[p_{t.}]/p_{t.}^2) \tag{5}$$

Reliable estimates (estimates of total escapement will be within ± 20%, 90% of the time) of escapement can only be achieved after 1 July (Table 3) or when 50% of the spawning escapement has been realized at the weir (Figure 11).

The timing data that describes the cumulative harvests can also be used in-season to estimate the expected total spawning escapement using equation 4. Since the sport fishery, on average, has historically exploited an average of 40% of the total return, spawning escapement can be estimated as the product of the estimated sport harvest times 1/0.40. Reliable estimates (estimates of total escapement will be within ± 20%, 90% of the time) using this approach, however, can only be achieved after 3 July for the confluence fishery and 8 July for the river fishery (Table 3, Figures 12 and 13). Since only 3 years of creel data are available to compute the timing data base, the reliability of this method of forecasting spawning escapement should improve with the addition of more years of creel data to the data base.

Both of these methods of projecting final spawning escapements of early-run sockeye salmon have limited applicability. Although early-run spawning escapements can be projected after 1 July based on weir counts, 50% of the run has historically been passed through the weir. Also, by 1 July, about 80% of the harvest in the confluence fishery and 70% of the harvest in the river fishery has historically occurred. Projections based on harvests in the river and confluence segments of the sport fishery also have limited applicability. Accurate projections of ultimate spawning escapements can only be made after 3 July for the confluence fishery and 8 July for the river fishery, after which about 90% of the harvest in each fishery has already occurred.

Improvements in projecting ability are possible by examining potential sources of variation in the predictive relationships. This approach has been used with success in projecting returns of chinook salmon to the Yukon River (Mundy 1985). As is the case with the early-run returns of sockeye salmon to the Russian River, the migratory timing of the chinook salmon returns to the lower Yukon River exhibit a high degree of annual variability. Much of this

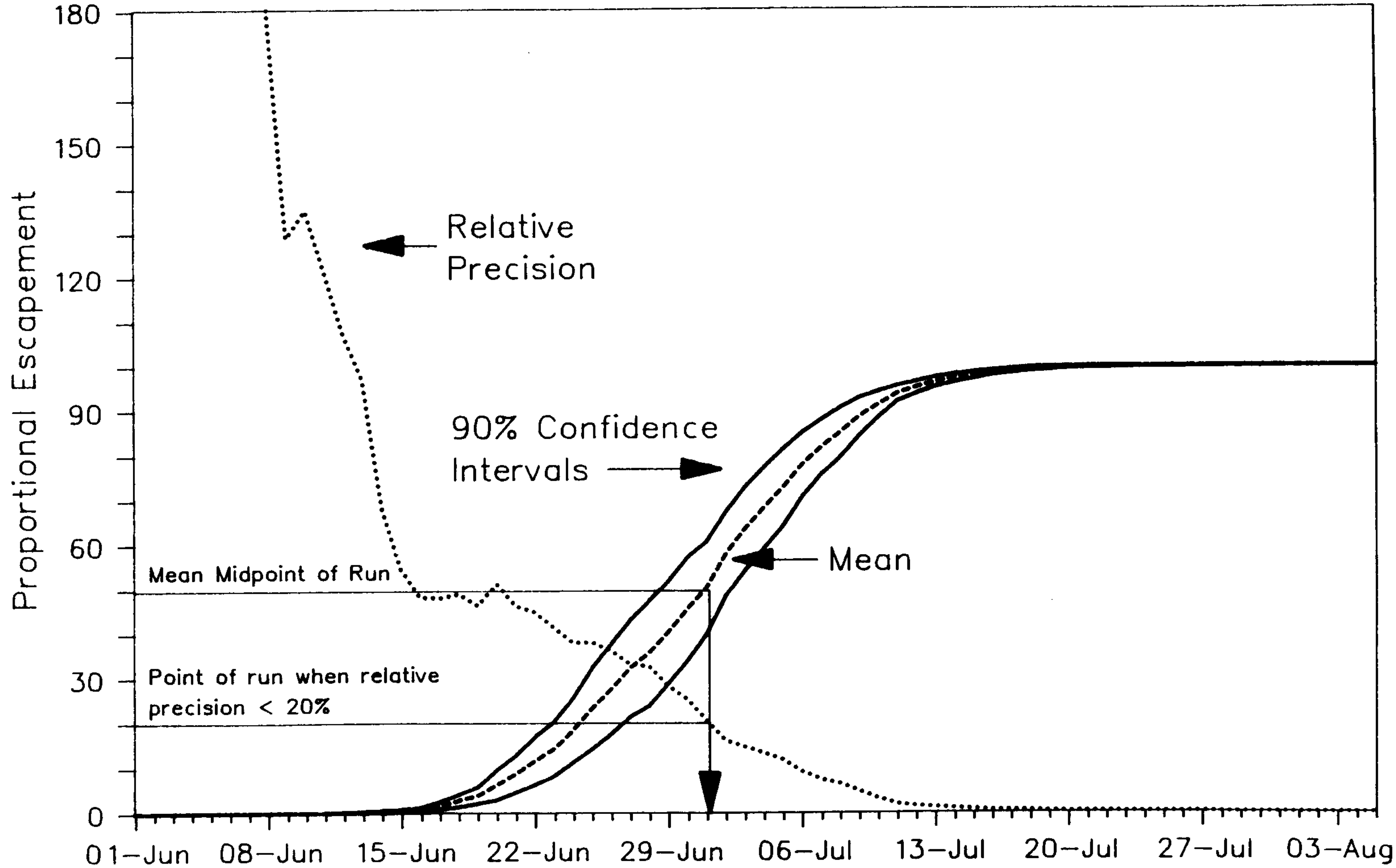

Figure 11. Cumulative proportions for spawning escapements of early-run sockeye salmon returning to the Russian River weir, Alaska, 1978-1989.

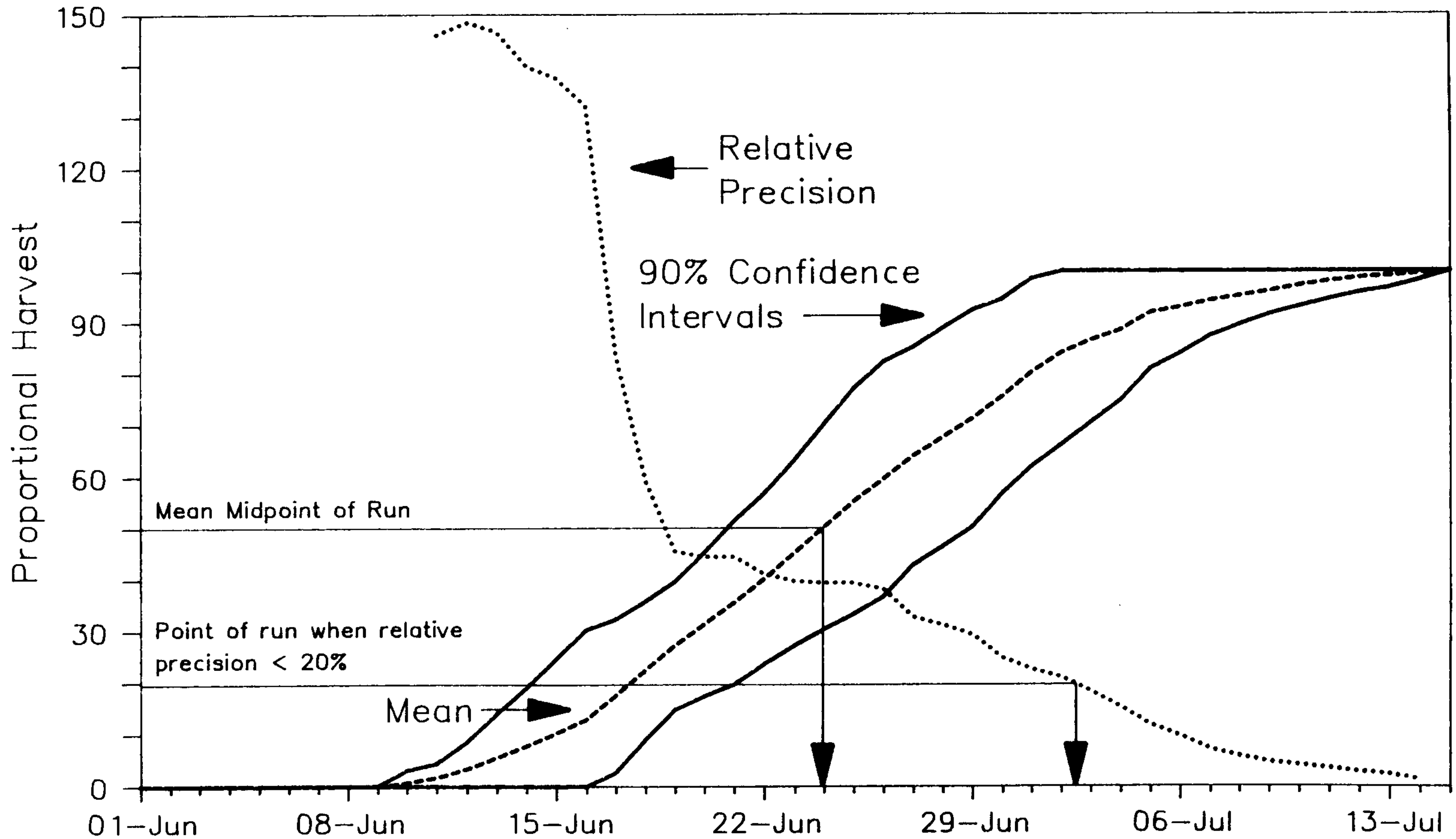

Figure 12. **Cumulative proportions for harvest from the confluence segment of the sport fishery on the early-run return of sockeye salmon to the Russian River, Alaska, 1986-1988.**

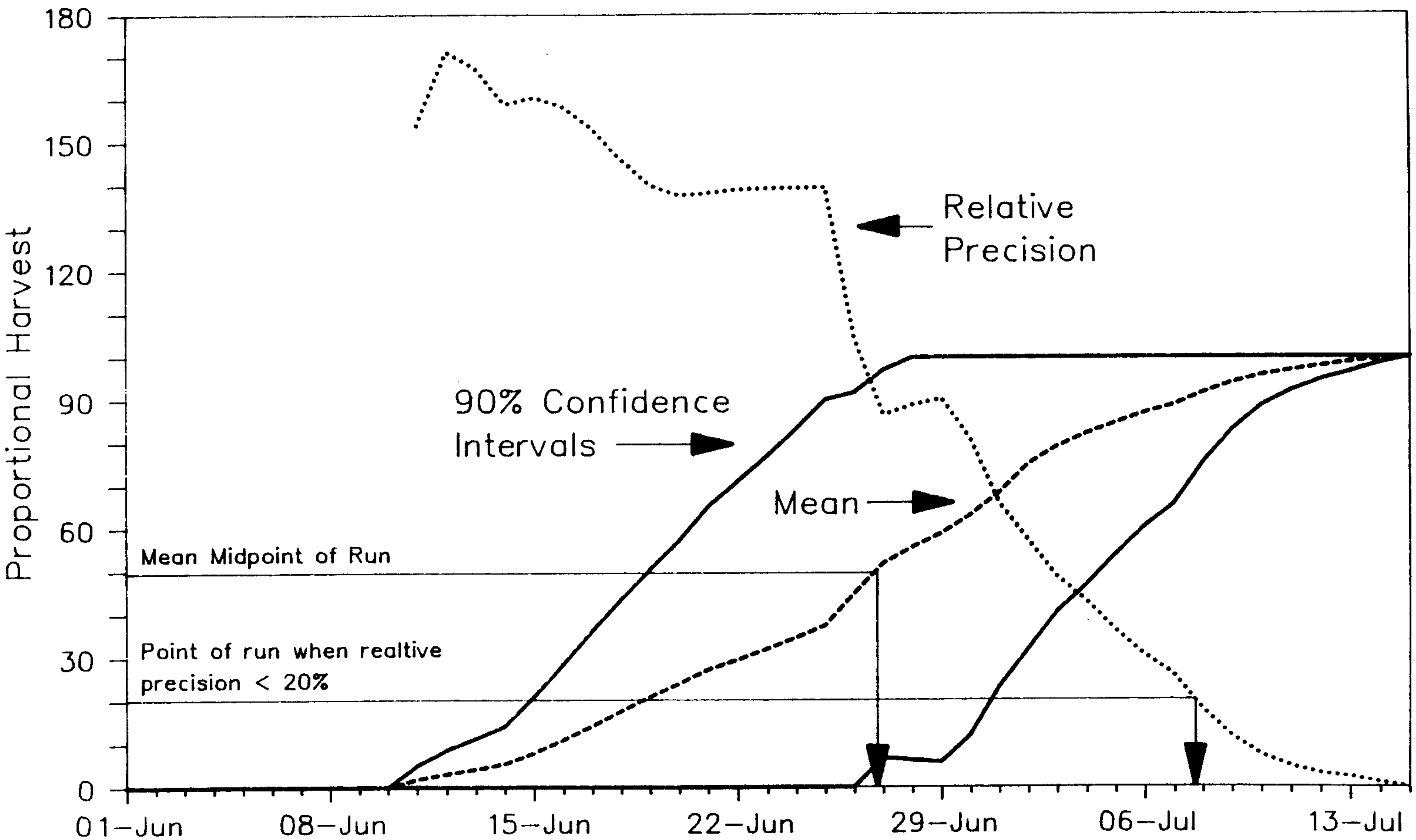

Figure 13. Cumulative proportions for harvest from the river segment of the sport fishery on the early-run return of sockeye salmon to the Russian River, Alaska, 1986-1988.

variability in the lower Yukon River chinook salmon timing, however, could be explained by annual variation in mean April air temperatures. We find that mean May air temperatures measured at the Kenai airport can account for about 53% of the observed variability in the timing of the early-run returns of sockeye salmon to the Russian River (Figure 14). There appears to be early returns which are associated with warm mean May air temperatures (Table 3, Figure 15A) and late returns associated with cool May air temperatures (Table 3, Figure 15B).

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We wish to express our gratitude to the former project leaders (in particular Larry Engel and Dave Nelson) and members of their field crews whose diligence in collecting and analyzing historical return data made this analysis possible. We also wish to thank Pat Hansen for her careful review of this document and help with the analytical aspects of this report. We also wish to thank Paul Krasnowski, Dave Bernard, and Doug McBride for their useful discussions in formulating the escapement goals. Lastly, we would also like to acknowledge funding for this project provided through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-5, Job No. S-32-3.

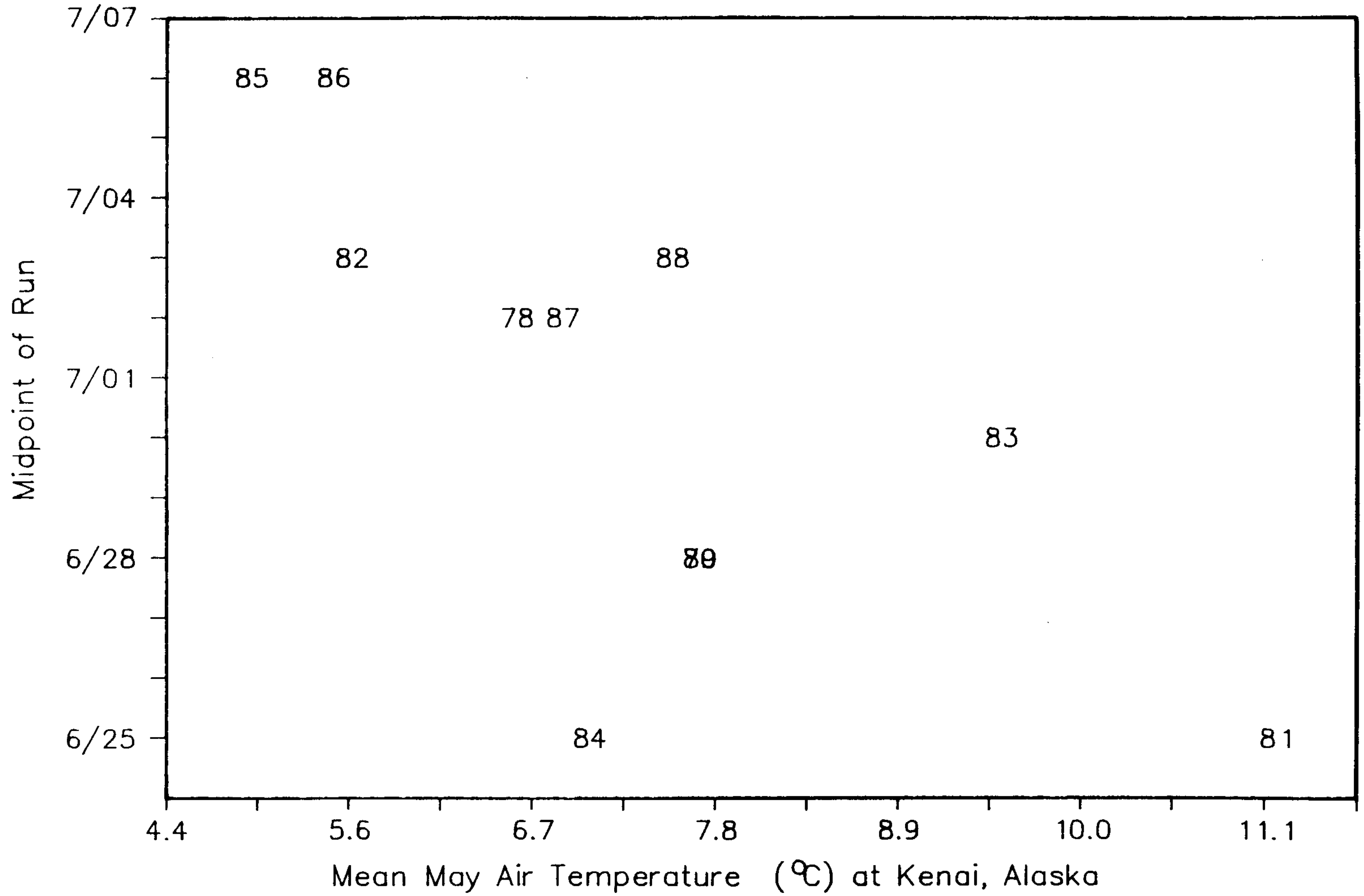

Figure 14. Relationship between mean May air temperatures and the timing of the early-run returns of spawning sockeye salmon through the weir at the outlet of Lower Russian Lake, Alaska, 1978-1988.

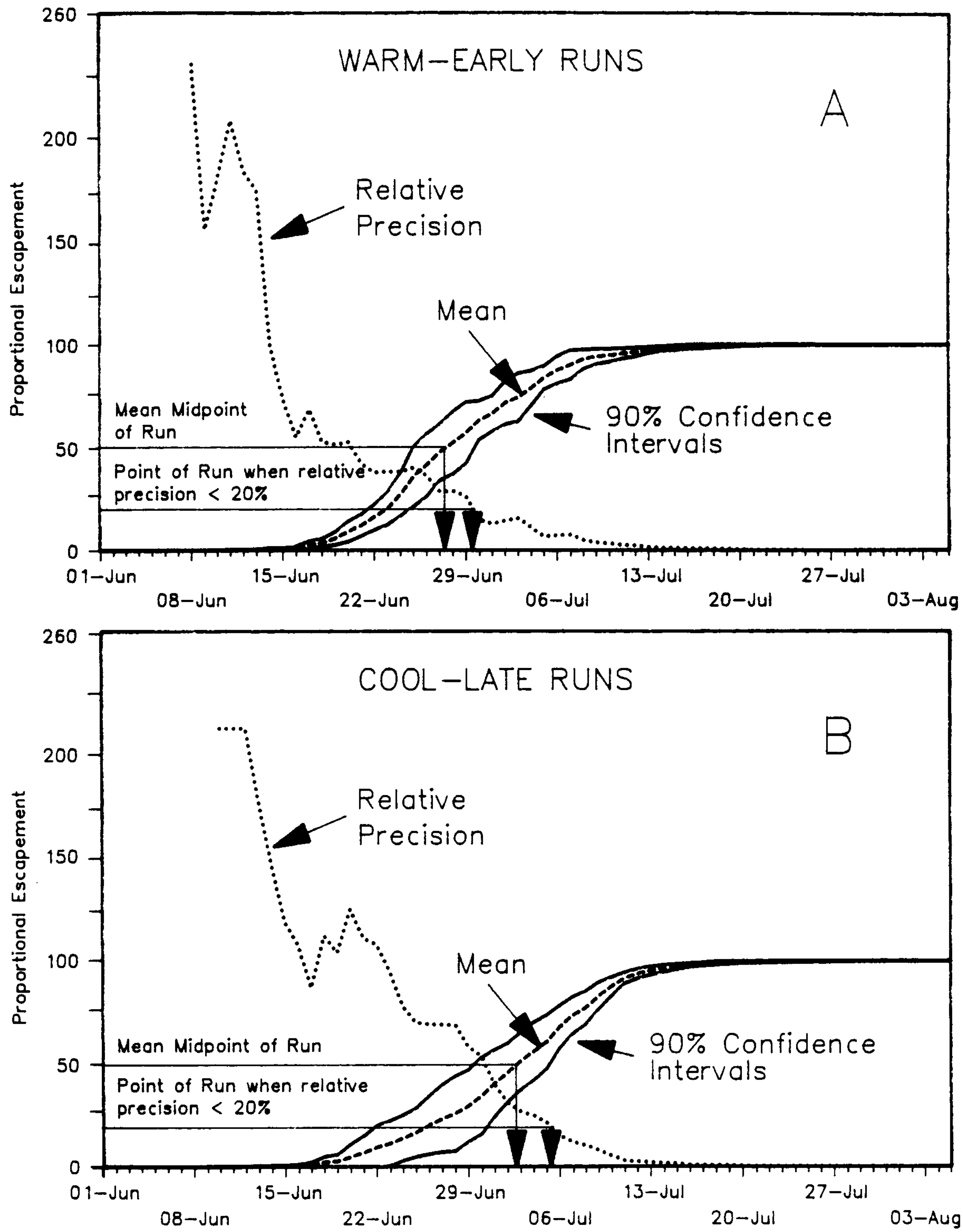

Figure 15. Cumulative proportions of spawning escapements for the warm-early and cool-late returns of early-run sockeye salmon to the Russian River weir, Alaska, 1978-1989.

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APPENDIX A

Russian River Sockeye Salmon Management Plan

Appendix A1. Russian River Sockeye Salmon Management Plan

5 AAC 21.361. RUSSIAN RIVER SOCKEYE SALMON MANAGEMENT PLAN. (a) The purpose of this management plan is to insure an adequate escapement, as determined by the Department, of sockeye salmon into the Russian River system and to provide management guidelines to the Department in an effort to preclude allocation conflicts between various users of this resource.

(b) Early Russian River sockeye salmon stocks have been harvested primarily by the recreational fishery since 1974. Since the bulk of the early Kenai River system sockeye salmon (those salmon passing the Department sonar counter located near Soldotna before June 21) run is comprised of Russian River system sockeye salmon stocks, they will be managed by the Department in the Kenai-Russian River systems to achieve a minimum escapement of 9,000.

(c) Late Russian River system salmon stocks are harvested in both the Cook Inlet commercial salmon gill net and Kenai-Russian River recreational fisheries. Since, at the present time, the Department is unable to separate these fish "in-season" from other Kenai River system sockeye salmon stocks it will not always be possible to allow a sufficient number of sockeye salmon into the Russian River system to meet both the spawning escapement and recreational angler needs. When this situation occurs, the Department will attempt to achieve a minimum escapement of 30,000 sockeye salmon into the Russian River system.

(d) Early and late Russian River system sockeye salmon are discrete stocks with established escapement goals. Because of this, they will be managed by the Department as a separate entity without regard to Kenai River system sockeye salmon run size. The Russian River sockeye salmon harvest, therefore, will not be included in the Kenai River system recreational harvest quota outlined in sec. 360(c) of this chapter.

(e) When the department determines that late Russian River system sockeye salmon stocks are comprising the majority of the Kenai River sockeye salmon run, appropriate restrictions will be placed on the various fisheries to protect the remaining Kenai River system sockeye salmon escapement.

APPENDIX B

Return and Timing Statistics for Returns of Sockeye Salmon to the Russian River

Appendix B1. Brood table of early-run returns of sockeye salmon to the Russian River, Alaska.

Brood Year	Number of Spawners	Age Composition of Return 1.2	1.3	2.2	2.3	Total Return
1969	5,000	0	6,720	1,234	5,315	13,269
1970	5,450	0	126	1,351	11,300	12,777
1971	2,650	28	254	1,989	5,397	7,668
1972	9,270	2,929	28,337	2,261	66,479	100,006
1973	13,120	438	1,941	3,234	20,935	26,548
1974	13,150	216	1,264	5,873	45,271	52,624
1975	5,640	0	4,528	2,403	9,016	15,947
1976	14,700	3,465	14,783	6,021	89,040	113,309
1977	16 070	2,008	1,087	362	14 218	17 675
1978	35 850	0	11,055	828	5 053	16 936
1979	19 700	3,310	56,173	389	34 971	94 843
1980	28,670	3,109	3,090	3,990	32,798	42,987
1981	21,140	430	9,697	21,462	43,722	75,311
1982	56,110	7,273	162,612	9,046	95,055	273,986
1983	21,210	0	3,847	1,519	17,914	23,280
1984	28,910	810	4,148	4,324	29,519	38,801

Appendix B2. Cumulative proportions for spawning escapements of early-run sockeye salmon to the Russian River weir, Alaska.

															90% CI[a]		REL.
Date	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	MEAN	VAR	LOWER	UPPER	PRE[b]
01-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
02-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
03-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
04-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
05-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
06-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
07-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
08-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.810
09-Jun	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.294
10-Jun	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.358
11-Jun	.003	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000	.000	.001	.000	.000	.002	1.220
12-Jun	.008	.000	.000	.000	.000	.001	.009	.000	.000	.000	.000	.000	.001	.001	.000	.003	1.077
13-Jun	.012	.001	.000	.000	.000	.001	.010	.000	.000	.001	.000	.000	.002	.001	.000	.004	.974
14-Jun	.012	.002	.001	.010	.000	.003	.017	.000	.000	.003	.000	.000	.004	.003	.001	.007	.688
15-Jun	.012	.007	.002	.010	.001	.004	.017	.001	.000	.014	.000	.000	.006	.003	.002	.009	.549
16-Jun	.016	.011	.024	.012	.001	.004	.018	.003	.000	.018	.000	.000	.009	.007	.004	.013	.484
17-Jun	.016	.017	.055	.023	.002	.008	.032	.003	.000	.026	.030	.000	.018	.027	.009	.026	.483
18-Jun	.023	.027	.068	.036	.002	.017	.047	.005	.000	.033	.084	.000	.028	.074	.014	.043	.493
19-Jun	.033	.029	.100	.060	.002	.035	.080	.005	.000	.048	.094	.000	.041	.134	.021	.060	.466
20-Jun	.043	.041	.130	.094	.002	.053	.151	.005	.001	.061	.191	.002	.064	.410	.031	.098	.515
21-Jun	.106	.070	.168	.125	.002	.082	.183	.005	.005	.078	.241	.002	.089	.634	.047	.131	.465
22-Jun	.175	.090	.181	.172	.007	.130	.248	.005	.006	.089	.307	.004	.118	1.043	.064	.171	.451
23-Jun	.198	.126	.254	.190	.035	.152	.309	.005	.016	.115	.331	.005	.145	1.338	.084	.205	.416
24-Jun	.219	.213	.262	.240	.139	.213	.451	.005	.018	.130	.348	.005	.187	1.876	.115	.258	.382
25-Jun	.227	.239	.314	.504	.228	.234	.514	.005	.027	.160	.368	.005	.236	2.991	.145	.326	.382

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Appendix B2. (Page 2 of 3).

Date	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	MEAN	VAR	90% CI[a] LOWER	90% CI[a] UPPER	REL. PRE[b]
26-Jun	.255	.336	.363	.548	.340	.251	.585	.005	.031	.192	.415	.020	.278	3.739	.177	.379	.362
27-Jun	.270	.470	.425	.588	.388	.296	.618	.005	.036	.242	.484	.074	.325	4.313	.216	.433	.333
28-Jun	.298	.615	.470	.607	.414	.296	.635	.013	.037	.273	.546	.102	.359	5.077	.241	.477	.327
29-Jun	.331	.680	.560	.620	.432	.332	.670	.039	.089	.343	.562	.199	.405	4.835	.290	.520	.283
30-Jun	.379	.717	.624	.648	.456	.488	.693	.091	.115	.390	.658	.227	.457	4.944	.341	.573	.253
01-Jul	.437	.754	.647	.654	.465	.544	.728	.218	.194	.441	.703	.278	.505	3.965	.401	.609	.205
02-Jul	.522	.766	.712	.702	.480	.569	.839	.316	.242	.501	.705	.622	.581	3.226	.488	.675	.161
03-Jul	.607	.801	.737	.727	.501	.578	.880	.363	.315	.573	.742	.819	.637	3.218	.543	.731	.147
04-Jul	.681	.829	.740	.772	.546	.701	.908	.402	.352	.647	.755	.883	.685	3.062	.593	.776	.133
05-Jul	.723	.833	.779	.819	.608	.847	.926	.457	.408	.676	.782	.897	.730	2.726	.643	.816	.118
06-Jul	.754	.875	.800	.843	.714	.906	.966	.536	.537	.711	.829	.897	.781	1.892	.709	.852	.092
07-Jul	.770	.960	.809	.859	.786	.918	.966	.582	.675	.729	.880	.900	.820	1.382	.758	.881	.074
08-Jul	.797	.975	.874	.909	.828	.918	.979	.630	.746	.740	.902	.928	.852	1.132	.797	.908	.065
09-Jul	.831	.982	.909	.917	.891	.930	.981	.713	.816	.799	.931	.953	.888	.670	.845	.930	.048
10-Jul	.871	.983	.919	.926	.922	.944	.983	.794	.870	.858	.946	.962	.915	.321	.885	.944	.032
11-Jul	.914	.984	.935	.937	.942	.956	.986	.914	.892	.879	.964	.970	.939	.119	.921	.957	.019
12-Jul	.942	.986	.949	.942	.954	.963	.987	.929	.929	.899	.980	.975	.953	.071	.939	.967	.014
13-Jul	.961	.992	.970	.958	.969	.968	.992	.931	.950	.924	.985	.979	.965	.048	.953	.976	.011
14-Jul	.973	.994	.980	.969	.980	.977	.995	.944	.960	.943	.992	.979	.974	.030	.965	.983	.009
15-Jul	.980	1.000	.982	.975	.986	.977	.998	.967	.961	.952	.992	.979	.979	.020	.972	.986	.007
16-Jul	.986	1.000	.990	.991	.989	.977	1.000	.979	.965	.974	.994	.987	.986	.010	.980	.991	.005
17-Jul	.988	1.000	.990	1.000	.992	.978	1.000	.987	.971	.981	.998	.994	.990	.008	.985	.995	.004
18-Jul	.991	1.000	.997	1.000	.995	.981	1.000	1.000	.976	.984	.999	.995	.993	.006	.989	.997	.004
19-Jul	.994	1.000	.999	1.000	.997	.985	1.000	1.000	.981	.991	.999	.996	.995	.004	.992	.998	.003
20-Jul	.995	1.000	1.000	1.000	.998	.991	1.000	1.000	.984	.994	1.000	1.000	.997	.002	.994	.999	.002

-Continued-

Appendix B2. (Page 3 of 3).

Date	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	MEAN	VAR	90% CI[a] LOWER	90% CI[a] UPPER	REL. PRE[b]
21-Jul	.996	1.000	1.000	1.000	.999	.996	1.000	1.000	.985	.995	1.000	1.000	.997	.001	.995	1.000	.002
22-Jul	.998	1.000	1.000	1.000	.999	.997	1.000	1.000	.987	.996	1.000	1.000	.998	.001	.996	1.000	.001
23-Jul	1.000	1.000	1.000	1.000	1.000	.998	1.000	1.000	.989	.996	1.000	1.000	.998	.000	.997	1.000	.001
24-Jul	1.000	1.000	1.000	1.000	1.000	.998	1.000	1.000	.991	.997	1.000	1.000	.998	.000	.997	1.000	.001
25-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.992	.997	1.000	1.000	.999	.000	.997	1.000	.001
26-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.993	.997	1.000	1.000	.999	.000	.998	1.000	.001
27-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.996	.998	1.000	1.000	.999	.000	.999	1.000	.000
28-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.996	.998	1.000	1.000	.999	.000	.999	1.000	.000
29-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.997	.999	1.000	1.000	.999	.000	.999	1.000	.000
30-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.999	1.000	1.000	.999	.000	.999	1.000	.000
31-Jul	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.998	.999	1.000	1.000	.999	.000	.999	1.000	.000
01-Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	1.000	1.000	1.000	.999	.000	.999	1.000	.000
02-Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999	1.000	1.000	1.000	1.000	.000	1.000	1.000	.000
03-Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.000	1.000	1.000	.000
04-Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.000	1.000	1.000	.000
05-Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.000	1.000	1.000	.000

[a] Confidence Intervals

[b] Relative Precision ($\alpha = 0.10$)

Appendix B3. Cumulative proportions for harvest from the confluence segment of the sport fishery on the early-run return of sockeye salmon to the Russian River, Alaska.

						90% CI[a]		
Date	1986	1987	1988	MEAN	VARIANCE	LOWER	UPPER	REL. PRE.[b]
01-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
02-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
03-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
04-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
05-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
06-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
07-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
08-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
09-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
10-Jun	0.000	0.025	0.000	0.008	0.000	0.000	0.033	
11-Jun	0.000	0.028	0.028	0.019	0.000	0.000	0.046	1.460
12-Jun	0.000	0.047	0.058	0.035	0.001	0.000	0.088	1.484
13-Jun	0.000	0.082	0.090	0.057	0.002	0.000	0.141	1.465
14-Jun	0.003	0.116	0.121	0.080	0.004	0.000	0.192	1.398
15-Jun	0.006	0.158	0.150	0.104	0.007	0.000	0.248	1.376
16-Jun	0.013	0.202	0.178	0.131	0.011	0.000	0.304	1.321
17-Jun	0.079	0.248	0.204	0.177	0.008	0.029	0.325	.836
18-Jun	0.140	0.298	0.239	0.226	0.006	0.092	0.360	.593
19-Jun	0.196	0.344	0.281	0.274	0.005	0.149	0.398	.456
20-Jun	0.229	0.395	0.321	0.315	0.007	0.175	0.455	.445
21-Jun	0.257	0.445	0.371	0.357	0.009	0.198	0.517	.446
22-Jun	0.293	0.482	0.436	0.404	0.010	0.238	0.570	.411
23-Jun	0.331	0.523	0.509	0.454	0.011	0.274	0.635	.398
24-Jun	0.369	0.564	0.582	0.505	0.014	0.306	0.704	.394
25-Jun	0.407	0.607	0.650	0.555	0.017	0.336	0.774	.395
26-Jun	0.443	0.651	0.697	0.597	0.018	0.369	0.825	.382
27-Jun	0.503	0.678	0.745	0.642	0.016	0.432	0.853	.328
28-Jun	0.542	0.705	0.789	0.678	0.016	0.467	0.890	.312
29-Jun	0.581	0.736	0.827	0.715	0.015	0.505	0.924	.293
30-Jun	0.638	0.773	0.860	0.757	0.012	0.569	0.945	.249
01-Jul	0.692	0.814	0.907	0.804	0.012	0.622	0.986	.226
02-Jul	0.738	0.838	0.949	0.841	0.011	0.664	1.000	.211
03-Jul	0.778	0.854	0.965	0.866	0.009	0.707	1.000	.183
04-Jul	0.811	0.875	0.970	0.885	0.006	0.750	1.000	.153
05-Jul	0.853	0.923	0.981	0.919	0.004	0.811	1.000	.118
06-Jul	0.875	0.933	0.981	0.930	0.003	0.840	1.000	.097
07-Jul	0.902	0.942	0.982	0.942	0.002	0.874	1.000	.072
08-Jul	0.918	0.952	0.984	0.951	0.001	0.896	1.000	.058
09-Jul	0.933	0.963	0.986	0.961	0.001	0.916	1.000	.047

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Appendix B3. (Page 2 of 2).

Date	1986	1987	1988	MEAN	VARIANCE	90% CI[a] LOWER	90% CI[a] UPPER	REL. PRE.[b]
10-Jul	0.946	0.974	0.994	0.971	0.001	0.931	1.000	.041
11-Jul	0.958	0.985	0.998	0.980	0.000	0.946	1.000	.035
12-Jul	0.968	0.992	1.000	0.987	0.000	0.958	1.000	.029
13-Jul	0.975	0.996	1.000	0.990	0.000	0.967	1.000	.023
14-Jul	0.987	1.000	1.000	0.996	0.000	0.982	1.000	.013
15-Jul	1.000	1.000	1.000	1.000	-0.000	1.000	1.000	

[a] Confidence Intervals
[b] Relative Precision ($\alpha = 0.10$)

Appendix B4. Cumulative daily proportional harvest statistics for the river segment of the sport fishery on early-run sockeye salmon return to the Russian River, Alaska.

						90% CI[a]		
Date	1986	1987	1988	MEAN	VARIANCE	LOWER	UPPER	REL. PRE.[b]
01-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
02-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
03-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
04-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
05-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
06-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
07-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
08-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
09-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
10-Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
11-Jun	0.000	0.036	0.024	0.020	0.000	0.000	0.052	1.542
12-Jun	0.000	0.066	0.031	0.032	0.001	0.000	0.088	1.712
13-Jun	0.000	0.085	0.044	0.043	0.002	0.000	0.115	1.673
14-Jun	0.000	0.104	0.063	0.055	0.003	0.000	0.144	1.590
15-Jun	0.000	0.154	0.089	0.081	0.006	0.000	0.211	1.606
16-Jun	0.000	0.206	0.126	0.111	0.011	0.000	0.286	1.584
17-Jun	0.000	0.256	0.176	0.144	0.017	0.000	0.364	1.533
18-Jun	0.005	0.300	0.227	0.178	0.024	0.000	0.437	1.460
19-Jun	0.014	0.352	0.267	0.211	0.031	0.000	0.507	1.401
20-Jun	0.019	0.395	0.311	0.241	0.039	0.000	0.574	1.377
21-Jun	0.019	0.443	0.360	0.274	0.050	0.000	0.653	1.382
22-Jun	0.019	0.482	0.392	0.298	0.060	0.000	0.711	1.390
23-Jun	0.019	0.518	0.430	0.322	0.071	0.000	0.771	1.393
24-Jun	0.019	0.555	0.472	0.349	0.083	0.000	0.835	1.395
25-Jun	0.019	0.591	0.520	0.377	0.097	0.000	0.903	1.395
26-Jun	0.129	0.628	0.593	0.450	0.078	0.000	0.920	1.043
27-Jun	0.212	0.667	0.682	0.520	0.071	0.070	0.971	.866
28-Jun	0.220	0.698	0.754	0.557	0.086	0.062	1.000	.889
29-Jun	0.228	0.731	0.810	0.589	0.100	0.057	1.000	.903
30-Jun	0.285	0.765	0.845	0.632	0.092	0.121	1.000	.809
01-Jul	0.378	0.800	0.874	0.684	0.072	0.233	1.000	.659
02-Jul	0.466	0.829	0.958	0.751	0.065	0.321	1.000	.572
03-Jul	0.540	0.856	0.984	0.793	0.052	0.407	1.000	.486
04-Jul	0.589	0.888	0.992	0.823	0.044	0.471	1.000	.428
05-Jul	0.644	0.903	0.994	0.847	0.033	0.541	1.000	.362
06-Jul	0.694	0.920	0.997	0.871	0.025	0.605	1.000	.305
07-Jul	0.735	0.932	0.999	0.889	0.019	0.657	1.000	.261
08-Jul	0.810	0.942	1.000	0.918	0.009	0.754	1.000	.179
09-Jul	0.871	0.950	1.000	0.940	0.004	0.830	1.000	.117
10-Jul	0.917	0.955	1.000	0.957	0.002	0.887	1.000	.073

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Appendix B4. (Page 2 of 2).

Date	1986	1987	1988	MEAN	VARIANCE	90% CI[a] LOWER	90% CI[a] UPPER	REL. PRE.[b]
11-Jul	0.948	0.958	1.000	0.969	0.001	0.923	1.000	.048
12-Jul	0.967	0.970	1.000	0.979	0.000	0.948	1.000	.032
13-Jul	0.974	0.991	1.000	0.988	0.000	0.966	1.000	.023
14-Jul	0.989	1.000	1.000	0.996	0.000	0.986	1.000	.011
15-Jul	1.000	1.000	1.000	1.000	0.000	1.000	1.000	.000

[a] Confidence Intervals
[b] Relative Precision ($\alpha = 0.10$)

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